CHAPTER XII GEOTECHNICAL

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12.1 Scope

The Subsidence Control Plan contained herein for Federal Coal Lease Salt Lake 062648, Tract I and Tract II containing 77.53 and 83.64 acres respectively with 161.17 acres in total, addresses specifically those items that are required by UMC 784.20 on pages 90-91 and UMC 817.121-.126 on pages 229-231 of the "Regulations Pertaining to Surface Effects of Underground Coal Mining Activities (including regulations for coal exploration), Final Rules of the Utah Board and Division of Oil, Gas and Mining," dated 9-20-82.

This plan is an amendment to the original application filed on December 17, 1980, by Genwal Coal Company, Inc. and the SUBSIDENCE CONTROL PLAN FOR GENWAL COAL COMPANY, INC. as prepared by David A. Skidmore and L.G. Manwaring of COAL SYSTEMS, INC. on August 28, 1981. The format of the currently approved COAL SYSTEMS report will be used with the conclusions based upon the results of the recent drilling of the Blind Canyon Seam which was obtained in April 1985 and the Hiawatha Seam data obtained to date due to mine development. The original application was submitted pursuant to the following: Title 40, Chapter 10, Utah Code annotated 1943, as amended, the "Cooperative Agreement between the United States Department of Interior and the State of Utah"; the Surface Mining Control and Reclamation Act (P.L. 95-87); and all regulations promulgated under those Acts affecting mining operation conducted in the State of Utah.

Since the original submittal, several operational and construction modifications have been submitted to satisfy regulatory compliance requirements.

12.3 Methodology

The following geotechnical description is based upon room and pillar mining using either conventional or continuous mining equipment followed by pillar extraction in the Hiawatha Seam. The mining plan has been developed to maximize the coal recovered in an economical manner.

Consideration was given to the subsidence experienced at nearby mines of similar overburden composition, on site inspections at the operating Crandall Canyon Mine and calculation based upon generally accepted formula using limited physical coal strength data in determining coal pillar sizes, barrier pillar design and direction of mining.

12.3 Underground Mine Design

The mine will be installed in an area of old works in the Hiawatha Seam. Coal was produced from this operation during the period 1940 through 1955 and was sold locally for domestic use.

Certain sections of the mine will be reopened so that water sump, ventilation and coal haulage facilities can be reestablished. Item XII-3 in the Appendix illustrates the manner in which the old workings were modified and repaired in order to bring them into compliance with modern regulations and the overall mining plans of Genwal Coal Company.

Where necessary, the workings were widened to accommodate a 42- inch coal haulage conveyor and proper supports will be

placed in areas of questionable roof control.

There is no way to monitor the effects of subsidence from the old workings. Item XII-3 indicates the preferred location of the intake, return and conveyor entries.

The mining operation will access only the Hiawatha seam by drifting into the seam from the coal outcrop as the recently completed drilling indicates no areas of mineable coal in the upper seams. The portal area for the Hiawatha seam will have three entries: one intake ventilation entry which will also serve as a haulage route, one neutral coal haulage conveyor entry and one return airway. The portal access area for the mine will have the necessary surface support items such as a fan, conveyor belt drive, power, etc.

The following description of the general mining sequence will apply to the Hiawatha seam. No development is anticipated in any of the upper seams as they are to thin to be economically recoverable. The projected mining plan for the Hiawatha seam is illustrated on Item XII-3 and as presented below:

1. Portal area excavated.
2. Actual portals established.
3. Permanent fan installation for exhaust ventilation.
4. North Mains developed.
5. North Mains completed to intersection with planned First West Mains.
6. First West Mains developed.
7. First West Mains completed.
8. Development of First South Panel off First West Mains.
9. Pillar recovery of First South Panel.
10. First South Panel sealed.
11. Development of Second South Panel off First West Mains.
12. Pillar recovery of Second South Panel.
13. Second South Panel sealed.
14. Development of North Mains into Tract II
15. Pillar recovery of barrier pillars and First West Mains.
16. Development of Second West Mains.
17. Pillar recovery of Second West Mains.
18. Development of Third West Mains.
19. Pillar recovery of Third West Mains.
20. Development of Fourth West Mains.
21. Pillar recovery of Fourth West Mains.
22. Pillar recovery of barrier pillars and North Mains.
23. Portal of mine sealed.

12.3.1 Geotechnical Tests and Analysis

The coal seam to be mined on the Genwal leases occur in the lower part of the Blackhawk Formation. The Formation is comprised of approximately 1000 feet of gray carbonaceous shales, siltstones, coals and interbedded sandstones of late Cretaceous Age. The Star Point Sandstone, a massive cliff forming 700 to 900 foot thick sandstone unit, underlies the

Blackhawk Formation and its top serves as a useful lithologic landmark in the area.

The formations in the area dip gently (1-3 degrees) westward off the west flank of the San Rafael Swell. The regional structure is broken by several north-south trending, high angle normal faults which offset the rocks from less than 1 foot to 250 feet or more.

The Hiawatha seam is the only seam to be mined on the lease with an average thickness of 6 feet. The coal heights encountered range from 5.5-6.5 feet except in the sandstone roll area as shown on Item XII-2. The coal within the permit area is a high volatile bituminous type. The seam will be entered into at an elevation of 7895 feet. Elevations within the mine range from 7892.1 to 7908.3 feet. The old works in the Hiawatha seam are accessible and it appears that the immediate roof is a competent sandstone, ranging from laminated to massive, interrupted by an occasional shale-siltstone lens varying in thickness from approximately 6 inches to 2 feet. Falls of roof in the old works are confined to the siltstone lenses and where observed are usually at intersections of rooms and entries. Falls are generally over the width of the opening extending rib to rib.

The floor of the coal seam grades from a clayey shale less than 1 foot thick to laminated sandstone, as observed in the old Hiawatha works.

No geotechnical tests were performed on the Hiawatha coal currently being produced. However, Seegmiller International of Salt Lake City reports an average uniaxial compressive strength of 2200 psi as being representative of the Hiawatha coal. The Blackhawk Engineering report, Coal Pillar Sizing, for the Genwal Mine, can be found in the Appendix as Item XII-6 which uses a range of 1200-1800 psi for the Hiawatha coal seam.

12.3.2 Coal Pillar Design

The pillar recovery plan currently approved by MSHA, DOGM and the USFS was designed by Genwal employees with the aid of MSHA Technical Support in Denver and information in a technical report COAL PILLAR SIZING, GENWAL MINE prepared by Mr. Dan W. Guy of Blackhawk Engineering Co. on 10/1/84. The approved pillar plan is preferred because of the inherent safety feature that a solid rib of coal will be on the miner operators right at all times as the actual mining takes place. The approved roof control and pillar recovery plan is included as Item XII-7.

The purpose of the Blackhawk Engineering Report was to evaluate the use of 60' x 60' centers on the entries and rooms during panel development as shown on the map in the

Appendix as Item XII-3 and in the pillar recovery plan Item XII-7. The major assumptions used in the analysis were an average coal compressive strength of 1400 psi, a mining height of 6 feet, an entry width of 20 feet, an overburden pressure gradient of 1 psi per foot of depth and a minimum acceptable safety factor of 1.3 in the panel areas. The conclusions of this report state that the remaining 40 foot square pillars will have a safety factor of 1.39 or greater in areas with less than 1000' of cover which is acceptable for short term entries. A copy of this report can be found in the Appendix as Item XII-6. If a less conservative uniaxial compressive strength is used in the Obert Formula, as recommended by Seegmiller International, of 2200 psi the safety factor becomes 2.19 at 1000 feet of cover for 40' * 40' coal pillars. The 40 foot square pillars are designed in areas that the overburden never reaches a value greater than 700 feet, refer to Item XII-2. Recalculation of the Obert Formula using a uniaxial compressive strength of 2200 psi, 700 feet of overburden and a 40 foot square pillar results in a safety factor of 3.12. The greatest coal height recorded during the development of the First South Panel was 6.3 feet as shown on Item XII-4, in good agreement with the 6 foot coal height assumption used in all calculations. A 3.12 factor of safety for the 40 foot square pillars is acceptable rather than using the recommended value of 4 in the SME Engineering Handbook, page 13-104, for the following reasons:

1. The length of pillar to average coal thickness ratio is 6.7. The SME Engineering Handbook on page 13-104 states that as this ratio approaches 12 that the pillars are regarded as being able to bear any load. The value of 6.7 is substantial in comparison to the limit of 12 justifying an allowance for safety factor reduction.
2. The First South Panel was developed and pillared using 40 foot square pillars without an occurrence of premature pillar failure or loss of coal recovery from roof support problems. The safety factor will now increase in the Second South Panel as the overburden is not as great as that experienced in the First South Panel, refer to Item XII-2.

Tract II panel development will use 60 foot square pillars. The coal height is expected to remain at 6 feet with a maximum of 1450 feet of overburden to be experienced in the northwest corner, refer to Item XII-2. Assuming a uniaxial compressive strength of 2200 psi and 20 foot entry development the resulting factor of safety is 2.54 using the Obert Formula. The ratio of pillar length to pillar height is now 10, very close to the value of 12 recommended in the SME Mining Engineering Handbook as described above. An allowance for safety factor reduction from the recommended 4 to 2.54 is justifiable for entry development with expected life less than one year for pillars with a substantial width to height ratio.

During secondary mining, half of the coal pillar is removed by taking four cuts across the side or across the front of the pillar as shown in the submitted Pillaring Plan which is currently approved by MSHA. A pillaring plan for the removal of the left and right side of adjacent pillars has also been approved for greater coal recovery. A copy of the Pillaring Plan can be found in the Appendix as Item XII-7. No bolting will be required after the panels have been developed and all additional roof support will be provided by timbers spaced on 5 foot centers. Controlled caving is anticipated once half the pillar has been removed and all personnel are clear of the area.

The sequence of pillar extraction is shown within the Pillar Recovery Plan. The pillars may be removed from either the right or left hand side as long as the row is pulled in its entirety from one direction. It is anticipated that this method of pillar removal will yield an overall recovery factor of near 80%.

The barrier pillar around the perimeter of the property has been designed according to Utah mining regulations which is based upon the following formula:

Width = 2 * coal thickness of coal to be extracted in feet+
5 * overburden thickness in feet / 100 +10 feet

The perimeter pillar on the north side of Tract II where the overburden reaches 1550 feet and the coal is assumed to remain at 6 feet in thickness will be 100 feet as shown on Item XII-3. The perimeter pillar along the west side of Tracts I & II will vary from 50 feet in the southwest corner to the 100 feet calculated above for the northwest corner. The perimeter pillar along the east side of Tracts I & II will vary from 80 feet in the northeast corner to 50 feet in the southeast corner.

12.3.3 Roof Span Design

No geotechnical tests have been performed on the immediate roof of the Hiawatha Seam to form a basis for quantitative analysis. It has been accepted practice in the Wasatch Plateau to use 20 foot entry and crosscut development widths. Experience in the Crandall Canyon Mine as well as in other mines in the area have justified the use of the 20 foot development width. No overall restrictions have been imposed on the use of 20 foot development entries neither by MSHA nor the Utah Mining Commission.

12.4 Subsidence Effects of Mining

An examination of the surface area as well as of state, federal and county records indicate there are no man-made structures, utility rights-of-ways and public or private resources necessitating protection from subsidence. The

occurrence of subsidence will not produce material damage or diminution of value or foreseeable use of lands.

12.4.1 Subsidence Mechanisms

The term "subsidence" applies to the deformation or movement in the overburden two or more mine entry heights above the immediate mine roof. The overburden thickness ranges from zero at the outcrop to approximately 1550 feet at the northwest corner of Tract II. The strength of the overburden is typical of the late Cretaceous sediments that are mined in Eastern Utah and Western Colorado.

It is accepted practice in this area to use two sources of information for subsidence evaluation. The sources are: 1) "Some Engineering Geologic Factors Controlling Coal Mine Subsidence in Utah and Colorado", Geological Survey Professional Paper 969, by C. Richard Dunrud, 1976, and 2) "SME Mining Engineering Handbook", Volume 1, by Arthur B. Cummins and Ivan A. Given, 1973.

The conclusions based upon the above source material are tempered by on site evaluation and actual experience based on similar mining conditions in late Cretaceous overburdens with similar thicknesses and strengths.

The surface area topography within the lease is shown on Item XII-1. The topographic map shows the relatively steep sloping sides of Crandall Canyon which contains the Crandall Canyon Creek. There is little or no talus slope and rock outcrops are abundant.

12.4.2 Projected Subsidence Effects

There are no man made structures within the permit boundary that will require subsidence control planning. The accompanying photo, Item XII-13 in the Appendix, and Items XII-1 and XII-4 of the area also confirm the above statement.

The surface in the area is controlled and administered by the US Forest Service with a small southern parcel of land owned by Beaver Creek Coal Co. which has been leased by Genwal as shown on Item XII-1. The land is used for domestic grazing in the areas of gentle slope and wildlife habitat over the total acreage. The vegetative resources will not be negatively impacted by subsidence so that the current land use is expected to continue.

The main objectives are to delineate the areas within the lease and adjacent lands that may be affected by subsidence and to determine the extent of the disturbance as shown in the Appendix as Item XII-5.

Significant guiding design criteria are as follows:

1. A 50 foot barrier pillar will be maintained on the lease directly adjoining the southern boundary and an approximate 100 foot barrier along the northern boundary. The eastern and western perimeter barrier pillars will vary from 50 to 100 feet as previously described.
2. Research indicates that a 30 degree positive limit "draw angle" should be used to project maximum extent of subsidence in the Eastern Utah/Western Colorado coal mining region as shown on Items XII-5 & XII-8. The angle of draw equal to 30 degrees will overestimate the projected outer limit of subsidence as confirmed by Dunrud's work in the Book Cliffs district of Utah and the Somerset district of Colorado. Dunrud determined the draw angle to vary from 15 - 21 degrees.
3. The area most likely to experience the maximum amount of subsidence is in the area of greatest coal thickness, which is 7 feet on the existing leases. Projected subsidence is shown on Item XII-5 in one foot increments.

Crandall Creek comes no closer than 110 feet horizontally and 50 feet vertically to the lease boundary as shown on Items XII- 1 and XII-8 which occurs in the southwest corner. Calculations and the results shown on Items XII-5 and XII-8 indicate that the subsidence will occur no closer than 190 feet from the centerline of Crandall Creek using a 30 degree angle of draw and a minimum 50 foot barrier pillar along the southern boundary. An angle of draw equal to 70 degrees or greater is required before the area within 40 feet of Crandall Creek becomes subject to any possible subsidence. This magnitude of draw angle in sandstone formations with minor shale partings is unrealistic. The barrier pillar shown on Item XII-4 has a 50 foot minimum width. The actual width shown was taken from Item XII-1 along the cross section line shown as it is in this area that the minimum distance between the caved area and Crandall Creek occurs. The angle of draw coincides with the single pillar bleeder line required to be left in place by the roof control and pillar recovery plan, refer to Item XII-7, and not the barrier pillar. The possible aerial extent of subsidence is shown on Item XII-5 as determined below:

Southwest Corner
Tangent 30 x 200 feet of overburden = 115.5 feet (use 115)
A radius of 115 feet was drawn on Item XII-5 to the west from the bleeder pillar and 90 feet to the south and southwest as described above and shown on Item XII-8 due to the surface topography. No additional barrier pillars will be required to protect Crandall Creek.

Northwest Corner of Tract I
Tangent 30 x 880 feet of overburden = 508.1 feet (use 510)

A radius of 510 feet from 80 feet within the northwest corner was drawn westward to inscribe an arc which defines the limit for possible subsidence.

Northwest Corner of Tract II
Tangent 30 x 1510 feet of overburden = 871.8 feet (use 875)
A radius of 875 feet from 100 feet within the northwest corner was drawn to define the limit for possible subsidence.

Northeast Corner of Tract II
Tangent 30 x 1110 feet of overburden = 640.9 feet (use 640)
A radius of 640 feet from 100 feet within the northwest corner was drawn to define the limit for possible subsidence.

Northeast Corner of Tract I
Tangent 30 x 560 feet overburden = 323.3 feet (use 325)
A radius of 325 feet from 50 feet within the northeast corner was used to inscribe an arc which defines the limit for possible subsidence. In this area Genwal had mistakenly mined outside the lease boundary which has been settled with the Federal Government.

Southeast Corner
The coal outcrops within the lease boundary in the southeastern region as shown on Item XII-2. It is questionable if any of the coal near the outcrop will be removed due to the weathered characteristics of the overburden and coal. The subsidence limit in the outcrop area will be assumed to occur at the outcrop. A line was then drawn from the coal outcrop along the southern boundary of Tract I to the limit determined above for the southwest corner as the ground contour lines increase at a gradual and near constant rate along the lease boundary and a similar barrier pillar will be required along this boundary as was required in the southwest corner.

A report prepared by Earthfax Engineering, Inc. dated June 12, 1985 is included within this permit as Item XII-? which pertains to the spring and seep inventory completed for the Crandall Canyon Mine. Earthfax reports finding a total of 80 springs and seeps, 29 of which were used by deer and/or elk with no development for human consumption occurring on any of the water sources discovered. 11 seeps and springs were found to occur within the area of possible subsidence. 9 of the total issue from the Blackhawk Formation with 2 seeps issuing from bedding planes in the Castlegate Sandstone. Only SP-38 and 42 have evidence of use by deer and elk with flow less than 1 gpm. SP-30 produces 1 gpm with no deer or elk use. Subsidence from mining in Tracts I & II will have minimal impacts on water supplies from seeps and springs in the vicinity of the mine. Displacement of wildlife due to subsidence will be minimal and the seeps and springs currently are an insignificant resource to the local

wildlife. SP-30 is located approximately 160 feet above the Hiawatha coal seam or nearly 25 times the seam thickness above the mine development elevation along a sandstone/shale interface. If subsidence is a result of repeated roof failure in the overburden then elastic deflection is believed to occur in the beds when a distance of 9 seam thicknesses has been traversed. SP-30 should show no effects due to subsidence as any water seepage through the shale layer due to tension cracking should become sealed due to clay migration. However, SP-30 will be monitored as described within this permit.

The magnitude of vertical subsidence is a function of coal height, overburden depth, stratigraphy, mining technique and distance from barrier pillars. According to Dunrud's work completed in 1980 based upon a study of subsidence in an underground coal mine at Somerset, Colorado published by the USGS in 1980, the maximum amount of subsidence expected is equal to 70% of the coal seam extracted, refer to Item XII-9. The maximum subsidence experienced for western coal mines according to Peng ranges from 33 to 65% of the coal height extracted. Gentry and Abel have cited examples with maximum subsidence ranging to 70% of the seam height for western US longwall operations. A 70 % value will be used within this report. The maximum value may be reduced by the amount of coal not recovered in the mining areas, i.e. 20% of the coal is expected to be unrecoverable in the pillared areas at the Crandall Canyon Mine. For the areas near an unmined solid pillar the maximum amount of subsidence is reduced according to the graph shown on Item XII-10 based upon referenced work in the United Kingdom by Gentry and Abel. The possible total subsidence is shown on Item XII-5 along with the limit of subsidence. The largest magnitude of subsidence anticipated is 3.9 feet at a point 40 feet east of the section line between Sections 5 and 6 and 1522 feet south of the section line between Sections 32 and 5 as shown on Item XII-5. The values were calculated by reducing the coal heights shown on Item XII-4 by 20% which represents the unrecoverable coal in the pillared areas (a 6 foot coal height was assumed in Tract II due to lack of data), then multiplying by 70% to obtain the maximum possible subsidence value as obtained from Item XII-9 which assumes a worse case scenario. The subsidence values were reduced according to Item XII-10 for areas that border a barrier pillar along the perimeter of the lease as shown on Item XII-3. A subsidence interval of 1 foot was used to construct this map.

Horizontal movement which would create slope failure is not expected to occur due to subsidence along the escarpment because only limited coal outcrop occurs within the lease. Within that area of old works no pillar extraction is anticipated.

Horizontal movement creating tension or compression cracks can not be projected due to the overburden thickness and lack

of jointing density and attitude data along the surface rock exposures.

12.4.3 Subsidence Control and Mitigation Methods

As previously presented within this report, no material damage or diminution of value or foreseeable use of lands is expected to occur. It has been presented that displacement of wildlife due to subsidence will be minimal as the springs within the potential subsidence limit are an insignificant resource.

There are no plans to backfill any area of the mine with waste material in order to reduce subsidence.

12.4.4 Subsidence Monitoring Plan

The US Forest Service has prepared an aerial monitoring system for the Crandall Canyon Mine which has been accepted for implementation. Vertical and horizontal control will be established on the 8 ground control stations before September 1985, refer to Item XII-12 for location. This method of subsidence monitoring has been accepted by other mines in the area and has met with DOGM approval. The program is included as Item XII-12.

The 8 survey control stations are outside the potential area of subsidence and can then be established according to standard surveying practice without the need of establishing subsidence monuments.

The following information will be forwarded to the proper authority when available:

1. A complete list of ground control stations with beginning horizontal and vertical coordinates.
2. A current map of the underground workings with areas delineated as to where the second mining will begin.
3. The date when second mining will commence and terminate.
4. The date of movement occurrence.
5. The total subsidence observed presented in map form as outlined within the monitoring plan.

12.5 Stability Analysis of Earthen Structures

No surface structures are required for Tract II. All earthen surface structure stability isaddressed in the original Tract I permit proposal.

12.5.1 Type of Structure
12.5.1.1 Hazard Considerations
Impounding
Non-impounding
Location
12.5.2 Construction Material Characteristics

12.5.3 Foundation Material Characteristics
12.5.4 Hydrologic Characteristics
12.5.5 Design and Construction Plans
12.5.6 Stability Analysis

12.6 Bibliography

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APPENDIX